

THE EFFECT OF NANO-ZINC OXIDE ON PARTICLEBOARD DECAY RESISTANCE

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ABSTRACT

The aim of this study was to investigate the decay resistance of particleboards treated with nano-zinc oxide against the white-rot fungus *Trametes versicolor* and the brown-rot species *Coniophora puteana*. The nanomaterial was used for manufacturing particleboards at 5, 10 and 15% wt based on the glue dry weight. The soil block decay test was performed according to *ASTM D 1413* (2007) using a 12 weeks incubation period. The results showed that all treated boards had good resistance against the decay fungi and the weight loss decreased in the samples with increasing nanomaterial loading. The threshold level of treated boards against fungal decay was obtained about 21% and 17% nano-ZnO against *C. puteana* and *T. versicolor*, respectively. Therefore, it had a positive effect on increasing particleboard resistance against the fungi. The maximum decay resistance (or minimum weight loss) occurred in the samples containing 15% zinc oxide nanoparticles.

Keywords: *Coniophora puteana*, decay resistance, nano-zinc oxide, particleboard, *Populus deltoides*, *Trametes versicolor*, weight loss.

INTRODUCTION

Wood is naturally made and consists of carbon hydrates and lignin in its structure. It can be destroyed by different factors such as UV rays, fungi, beetles, ants, marine borers and chemicals (Schmidt 2006). This fact decreases its durability in the wooden structures. Several processes have been suggested to increase the wood durability such as chemical preservation procedures. In recent years, the use of fungicides and insecticides has been met some limitations due to the environmental problems and therefore, the researchers are looking for alternative safe chemicals to increase the wood durability along with minimum damage to the environment (Dorau *et al.* 2004, Rezaei and Parsapajouh 2004).

Recently, the effects of nanomaterial utilization on improvement of the wood resistance against different wood destructive factors have been investigated in several studies (Clausen 2007, Freeman and McIntyre 2008, Kartal *et al.* 2009, Yu *et al.* 2010, Clausen *et al.* 2010, Clausen *et al.* 2011, Saha *et al.* 2011, Sahin and Mantanis 2011, Afrouzi *et al.* 2013). Nanoscale materials are defined as a set of substances where at least one dimension is less than approximately 100 nanometers (Siegel *et al.* 1999, Baer *et al.* 2003, Kafarski 2007). The two main reasons why materials at the nanoscale can have different properties are increased relative surface area and new quantum effects. Nanomaterials have a much greater surface area to volume ratio than their conventional forms, which can lead to greater chemical reactivity and affect their strength.

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Also at the nanoscale, quantum effects can become much more important in determining the materials properties and characteristics, leading to novel optical, electrical and magnetic behaviors (Alagarasi 2011).

Nano-zinc oxide (nano-ZnO) is a white powder that is insoluble in water, but soluble in weak and strong mineral acids, ammonia, acetic acid or formic acid. It is used in many industries due to its low cost and catalytic, electrical, electronic, optical and antimicrobial properties (Sato *et al.* 2003, Yang *et al.* 2004). It is used to produce sunscreens, cosmetics, coatings, optical and electronic devices (Yang *et al.* 2004, Dange *et al.* 2007). Zinc oxide is used as preservative, but when its particle size is reduced to the nanoscale, its reactivity extremely increases (Mende and MacManus-Driscoll 2007).

Clausen *et al.* (2009) used vacuum treated southern yellow pine and yellow poplar with 2,5 and 5% nano-ZnO to evaluate leaching, mold and decay inhibition, termite resistance, and visible signs of weathering. They observed that virtually no leaching occurred at any treatment concentration of nano-ZnO and all concentrations of the nanomaterial showed inhibition of termite feeding. Decay inhibition was variable. Nano-ZnO did not inhibit the brown rot fungi as well as soluble ZnSO₄ and the weight loss due to the white-rot fungi was inhibited by all tested nano-ZnO concentrations.

In another research carried out by Kartal *et al.* (2009), the leachability and efficacy of southern yellow pine treated with copper, zinc, or boron nanoparticles was evaluated against mould fungi, decay fungi, and Eastern subterranean termites. The results showed that nano-copper with or without surfactant, nano-zinc, and nano-zinc plus silver with surfactant resisted leaching compared to metal oxide controls. In addition, the nano-copper treated samples that were exposed to *Antrodia* sp., resulted in high weight loss (19 to 33 percent) and the unleached samples containing nano-boron and boric acid effectively inhibited all decay fungi. Nano-zinc possessed the most favorable properties such as leaching resistance, termite mortality, and inhibition of termite feeding and decay by white-rot fungi.

The goal of this study was to evaluate the efficacy of particleboards containing zinc oxide nanoparticles against the decay fungi. This is the first study to examine the resistance of particleboard containing nanomaterial against fungal decay.

MATERIAL AND METHODS

Cottonwood (*Populus deltoides*) sapwood obtained from the research forest in Shastkalateh, Golestan province, Iran, was chipped and air dried to 3% moisture content. Urea-formaldehyde glue was used at 12% wt (based on the wood dry weight). Nano-zinc oxide (Nano Pars Lima Co.) was added at 5, 10 and 15% wt (based on the glue dry weight) into the glue, mixed by ultrasonic devise UP400S and sprayed on the particles. The mat moisture content was 11%. It was pressed at 175 °C and a constant pressure of 30 kg/cm² for 6 minutes to manufacture the panels with a density of 0,75 g/cm³. Boards without nano-ZnO were prepared as control samples. The prepared boards had a thickness of 19 mm and were cut into 19 mm cubes and tested according to *ASTM D 1413* (2007) with 6 replications for each treatment-fungus combination. Water holding capacity of the soil was 130%. The white-rot fungus *Trametes versicolor* (L.) Lloyd strain (CTB 863 A) and the brown-rot fungus *Coniophora puteana* (Schumacher ex fries) Karesten (BAM Ebw. 15) were used to inoculate samples. The classification of resistance was done according to ASTM D2017 (2005) method.

RESULTS AND DISCUSSION

The results of Tukey statistical analysis test showed that there was a significant difference between WL of treated and untreated samples. Weight loss (%) was significantly more in the untreated samples and decreased with increasing nanomaterial loading in both fungi tested as shown in Table 1. Variance analysis of the factors affecting WL specified that the independent effect of fungus type and nano-ZnO loading on WL was significant in the 95% significance level.

The sample resistance against the white-rot fungus significantly increased with increment of nano-ZnO loading and the minimum WL occurred in the samples containing 15% nano-ZnO that was approximately 15 times lower than the untreated sample WL. Improving decay resistance may be due to the antifungal properties of zinc oxide nanoparticles (Kartal *et al.* 2009).

Table 1. Weight loss due to *Trametes versicolor* and *Coniophora puteana* attacks and classification of resistance.

Nano-zinc oxide loading (%)	<i>Trametes versicolor</i>		<i>Coniophora puteana</i>	
	Weight Loss (%)	ASTM D2017 rating	Weight Loss (%)	ASTM D2017 rating
0	45,5	Non-resistant	39.52	Moderately resistant
5	13,93	Resistant	16.43	Resistant
10	7,78	Resistant	12.69	Resistant
15	3,03	Highly resistant	7.23	Highly resistant

The untreated sample WL due to *Trametes versicolor* was more than *Coniophora puteana*. *C. puteana* as a brown-rot fungus primarily attacks the cellulose and hemicellulose and prefers softwoods while *T. versicolor*; as a simultaneous white-rot fungus, attacks both lignin and carbohydrates and favors hardwoods (Coggins 1980, Harsh and Tiwari 1990, Highley 1991, Curling and Murphy 2002, Schmidt 2006). It may justify more destruction and WL of the untreated samples prepared from poplar sapwood by *T. versicolor*. Higher degradation rate of mannans than cellulose and xylanes may lead to low destruction of hardwoods by *C. puteana* (Ritschkoff *et al.* 1992, Schmidt 2006).

A significant reduction occurred in the treated sample WL that was exposed to the brown-rot fungus and there was an inverse relation between WL and nano-ZnO loading. In addition, the treated sample WL due to the brown-rot fungus was more than the samples WL that were exposed to white-rot fungus, although the white-rot fungus can destroy other wood components in addition to lignin (Highley 1991). WL in the samples containing 15% nano-ZnO was 3,03 and 7,23% due to the white and brown rot fungi, respectively.

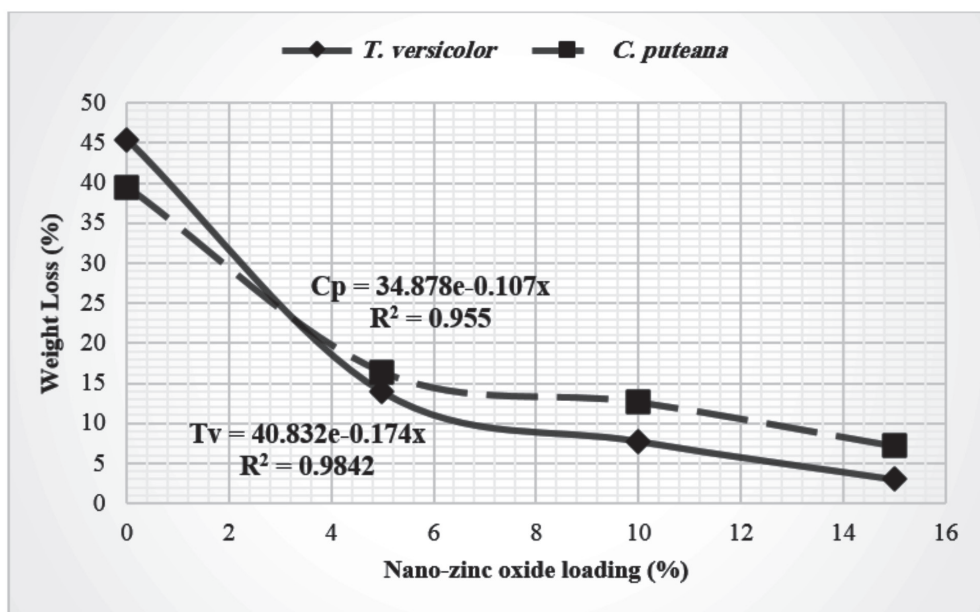


Figure 1. Changes trend of WL and nano-ZnO loading that determines the threshold level of treated boards against *Trametes versicolor* and *Coniophora puteana*.

Figure 1 shows the relation between nano-ZnO loading and the board WL for *C. puteana* and *T. versicolor*; whereby the threshold level of treated boards obtained about 21% and 17% nano-ZnO against *C. puteana* and *T. versicolor*, respectively. It means that *C. puteana* had more resistance against nano-ZnO and it slightly could preserve its destructive activity that resulted in more WL in spite of the antifungal effects of zinc oxide nanoparticles. Therefore, more nanoparticle loading is needed to achieve 0% WL in the samples that were exposed to the brown rot fungus. The antifungal properties of nano-ZnO is related to its interference in the cell wall structure and metabolism process and consequently cell death (Lia *et al.* 2009).

CONCLUSIONS

Nano-zinc oxide clearly was effective in the sample weight loss (WL) after exposing to wood destructive fungi. Sample WL decreased with increasing nanomaterial loading. The minimum WL occurred in the boards containing 15% nano-ZnO yielding high decay resistance. Nano-ZnO had good effects on preventing fungal decay and WL due to the white-rot fungus. Therefore, it can be used as a suitable preservative and filler in the wood composites. However, although the exploration of zinc oxide nanoparticles based products is booming in the various directions of consumer products, their comprehensive toxicological impact still remains unclear and should be considered when used for wood.

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